Virtual modelling in shipbuilding

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Abstract - The introduction to this paper copes with presentations of ship constructions and 3D visualizations in shipbuilding. The paper next considers the needs, methods and applications of virtual modelling in shipbuilding with emphasize on the application of Virtual Modelling Language – supporting the VRML format. Finally, the paper presents the experiences in conversion of smaller and bigger, partial and integral three dimensional models of ship construction into virtual models for active usage in real time and in network environment. The paper demonstrates that the creation of big virtual models in shipbuilding is a feasible task but requires a number of accommodations and optimization of the model size that affects the clarity of the model details as yet. The GRID application expectedly may contribute to photo-realistic visualization of large scale virtual models of ships in network environment. The conclusion supports the thesis that in the next future virtual models of complex ship structures will be the prevailing methods of presentation for practical and educational purposes, often as parts of more far-reaching virtual laboratories.

I. INTRODUCTION

Presentation of results of engineering design procedures, preparations for production, production itself, ship service, maintenance and education are important tasks for engineering theory and practice in shipbuilding and elsewhere. Models of different kinds such as for example the wooden admiralty models [1] of ships without shell plating were used for presentation of the ship hull properties of importance for structural arrangements, compartmentation, design of interior and placement of outfit or armaments aboard, Fig. 1.

Fig. 1. Admirality model of royal yacht Carolina from 1749 (Made by Stanko Crnjević 1994.)

Classification Societies recently pay more and more attention to life time service of ships giving an important role to 3D graphical models of ship structures, material distribution, structural modifications, repair, corrosion progression and ultimate loads. The Classification Society Det Norske Veritas (DNV) for example introduced the NAUTICUS 3D modeler [2] to facilitate hull inspection and maintenance of ships with 3D digital graphical models assigning an additional higher class to ships, Fig. 2. In ship design is appropriate and highly desired to present the entire hull structure by 3D model, such as for example provided by program TRIDENT developed by USCS from Pula for shipbuilding CAD/CAM practice [3], Fig. 3.

RINA (Classificazione navale, certificazione e servizi all'industria)- uses the open-source program CASCADE [4] for 3D presentation of the ship hull geometry and structural elements that are interchangeable with other programs for FEM analysis like Nastran Engine and for different programs for technical calculations like hull hydrostatics, hydrodynamics, stability, resistance and propulsion, sea keeping, compartmentation, safety, reliability, structural adequacy, optimization, efficiency, vibrations and so on.

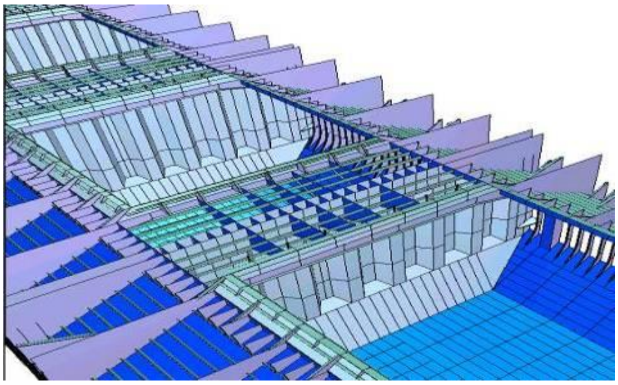


Fig. 2. 3D models of ship o DNV-NAUTICUS

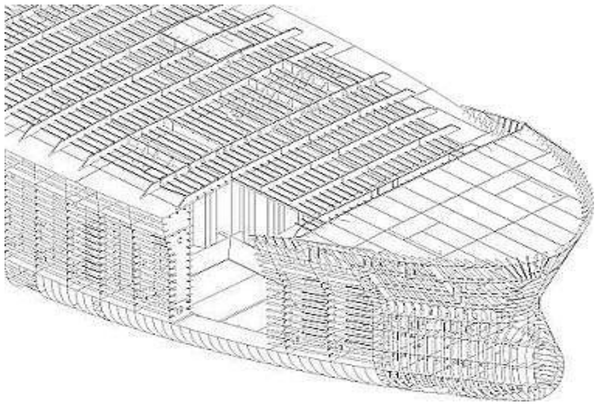


Fig. 3. 3D models of ship construction according to TRIDENT

This paper focuses on the facilities for virtual 3D photo realistic modelling of ships and marine objects and possibilities for interactive presentation of their static geometry as well as dynamic presentations of their motions in real time providing photo-realistic simulation capabilities in the network environment. The start of the study on the Department of Naval Architecture and Ocean Engineering was oriented to reviewing existing virtual models and appropriate procedures and on creation of smaller models of substructures for educational purpose. Later on the investigation proceeds on large CAD models in cooperation with USCS from Pula that provided 3D solid models of entire ship structures. The experiences are summarized in this paper.

II. GEOMETRIC MODELS

Computer based modelling investigates different ways of presentation not only of the geometry but also of all relevant related information needed for applications in constructing design processes, production, service and maintenance [5]. The three principal types of presentations in nowadays engineering practice are the following:

- Graphic models: consisting of graphic primitives, lines, arcs, text etc., Fig. 4.
- Surface models: consist of parametrically defined surfaces, Fig. 5.
- Solid models: decomposed, constructs and boundary models.

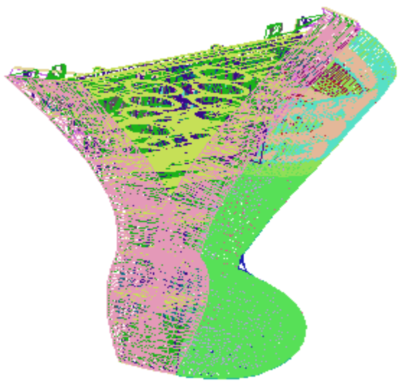


Fig. 4. Wire model

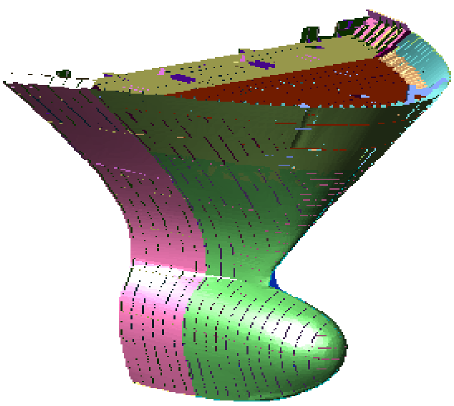


Fig. 5. Surface model

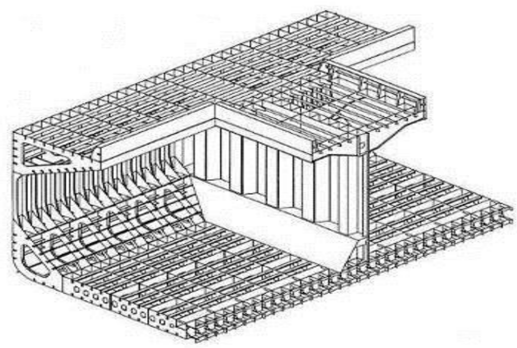


Fig. 6. Ship structure defined by solid elements

3D models produced by traditional CAD supporting programs can be statically viewed in different positions and angles but they are still not fully appropriate for interactive investigations and viewing in real time in network environment as it is presumed for virtual modelling, Fig. 6.

III. VIRTUAL MODELS

Virtual Reality Modelling Language (VRLM) format is a standard ASCII formatted file for 3D description of objects suitable for interactive work in network environment. Such a file consists of a sequence of instructions which are executable within a special application – VRML menus(preglednik) which serves as a plug-in program to the common Internet menus. This study employs the plug-in program «Cortona» from ParallelGraphics» [6] for presentation of VRLM files in network environment which normally can be installed in most of commonly adopted web-browsers. ParallelGraphics [6] was established in 1998. Since 2004 ParallelGraphics eneterd aviation industry such as Airbus [8] and Shipbuilding such as Admiralty Shipyards [9]. Since 2003 Boeing [7] uses VRLM format for aircraft and engine maintenance manuals. Such an approach, using ASCI files for description of executable programs and graphic functions are patterned after OpenInventor (SiliconGraphics Inc).

The higher level Application Program Interface (API) performs the sequences of instructions from ASCI files using graphical libraries such as OpenGL or Direct X for example. The VRML menus provide user interactions and the processing goes on with f program codes in Java or JavaScript within the VRML textual files. The VRML is a simple platform for interactive animation and simulation in 3D environment in real time that do not expose programmers to time consuming efforts when dealing with graphical libraries an lower level programming languages. Today is VRLM an adequate tool for virtual modeling particularly for educational purposes in the academic community. VRML is used for product development and virtual documentation and catalogues to support the Product Lifetime Management (PLM) and Product Data Management (PDM). Most of CAD software support transition from 3D models into VRLM formats.

3D models in VRLM consist of surface primitives for description of solid objects by approximation with finite number of graphical primitives, for example triangles. The finer approximations require more elements.

Some of CAD programs support 3D solid models that can be transferred into virtual models in VRML format. Such files then allow not only passive presentation but also interactive viewing. However, big files with virtual models that are stored on servers are not easily accessible to the remote users on other sites in the network and require significant reduction in size where high compression is needed by sending and appropriate decompression by receiving files at local sites. Conveniently web browsers like Internet Explorer (IE) are employed in combination with appropriate plug-in programs for the presentation of virtual models.

Navigation in 3D space implies three groups of instructions in Cortona program [6] for motion and viewing of virtual models stored in VRLM format:

1. Basic motions (def): **Walk** 

, **Fly** 

, **Study** 

2. Basic actions: **Plan** 

, **Pan** 

, **Turn** 

, **Roll** 

.

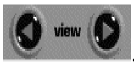
3. Starting positioning: **Goto** 

, **Align** 

,

Restore 

, **Fit** 

and **View** 

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Interfaces based only on CAD program features offer only four instructions: Zoom, Fit, Spin, Pan, that replace the „navigation“ motion ability with simple viewing of 3D models.

IV. Virtual Models in Shipbuilding

Virtual modelling in this study employs the potentialities of existing and commonly used CAD tools in engineering for generation of complex 3D models of ships. However, such models have to be adjusted by size and appearance for active interactive virtual real time presentation in network environment. Often adjustments lead to inevitable reduction of presentation quality.

The first approach to generation of virtual models in this study translates common AutoCAD drawings as solid or surface models into VRML formats Such an approach may require additional editing with more specialized programs such as 3DSMAX, Rhino or Maya, also needing optimization with, for example VIZu, 1.8 program, before installation on the server. For other complex forms or shapes of the ship hull some other problem oriented expert tools such as GeneralHidroStatics (GHS) programs can be used. For further processing by adding animations and different views useful tool is for example the 3DSMAX programs from AutoDesk package [10] which supports direct transformations to VRLM format, offering also opening data in dwg format or translation to VRLM format. In such a way some smaller examples of ship structures were prepared through student exercises on the Faculty of Mechanical Engineering and Naval Architecture, Figs. 7, 8.

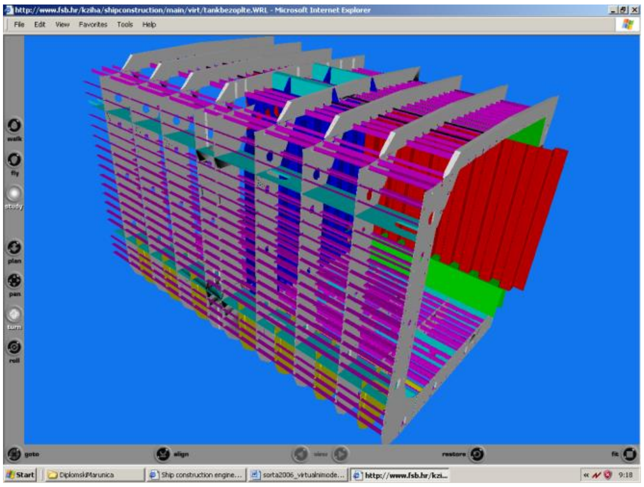

Fig. 7. Virtual presentation of tanker (no shell plating)

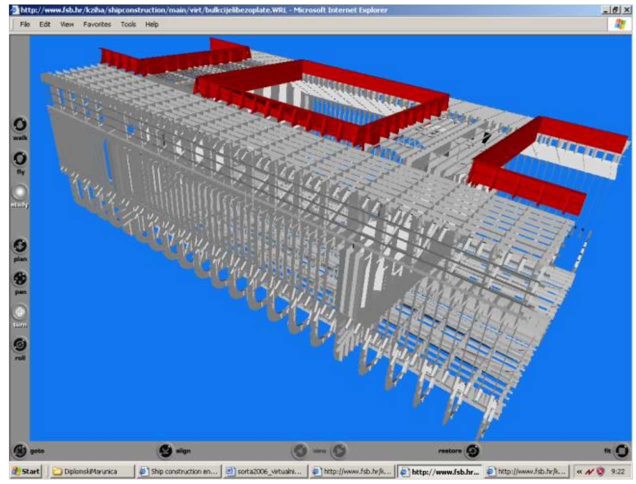

Fig. 8. Virtual presentation of a bulk carrier cargo compartments (no shell plating)

Some versions of AutoCAD programs support exporting files in VRML formats but plug-in programs could be required such as it is for example the Mechanical Desktop. In some cases VRML files can be transferred to AutoCAD by first importing to 3DSMAX and lately after additional editing and optimization exported as a file with dwg extension.

Big files for 3D presentations (over 50MB) have to be optimized, e.g. by using Internet Model Optimizer (additional licensed program for Cortona) or using VIZup program [11], Fig. 9. Optimization programs have to be employed carefully since they link small elements (triangles) and sometimes badly affect the clarity of views by loosing many important details.

For data interchange and transformations needed in virtual modelling international standards are set in order to support unified information models [12], such as STEP(ISO 10303) or formats for data interchange such as IGES or DXF used for CAD files developed by Autodesk for data interchange among different programs.
Two methods applied in this research for virtual modelling in network environment are elaborated in the sequel. The first approach is based on the generation of virtual models using adequate optimization program.

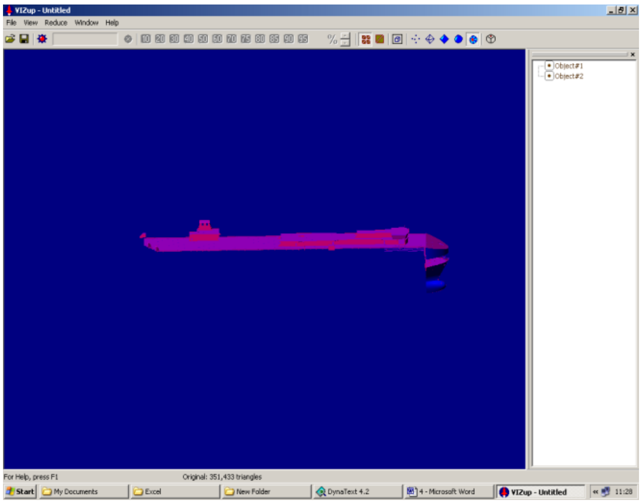

Fig. 9. VIZup 1.8 optimizer

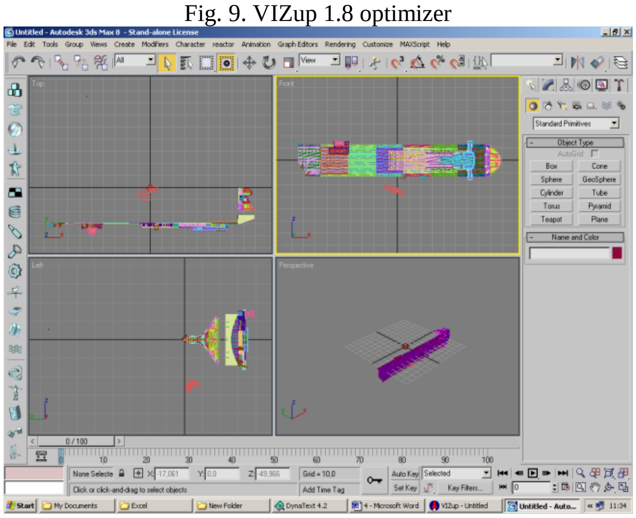

Fig. 10. 3DS MAX

For big VRLM files (with more than 500000 triangular details) that are not easily manageable by VIZup optimization program [11], manual splitting of files into smaller particles is needed, for example in Notepad and VRMLpad programs. Each file is then optimized separately depending on the object shape and the overall optimization level depends on desired clarity of details, Fig.9. The optimized files are imported in 3DSMAX program and the reduced object is exported as VRLM file, Fig. 10.

The second method is the creation of virtual model in 3DSMAX application [10] adequate for bigger models. If the files exceed, let's say 100MB, they have to be partitioned manually and each particle is then separately imported in 3DSMAX. To each part a new layer is assigned in order to avoid the situation that the ship is an unique big object when storing it in VRLM format. Such unuque models are hardly manageable in the network environment. Model partitions accommodate to network environment by collecting them using the VertexWeld function. Some details will be lost and compromising among larger and smaller sub-models is needed. Accommodation of the ship model in VRLM format is in final stage accomplished by importing 3ds files in 3DSMAX program when the model is positioned in the space, scaled according to its natural size and after completing with additional illuminations.

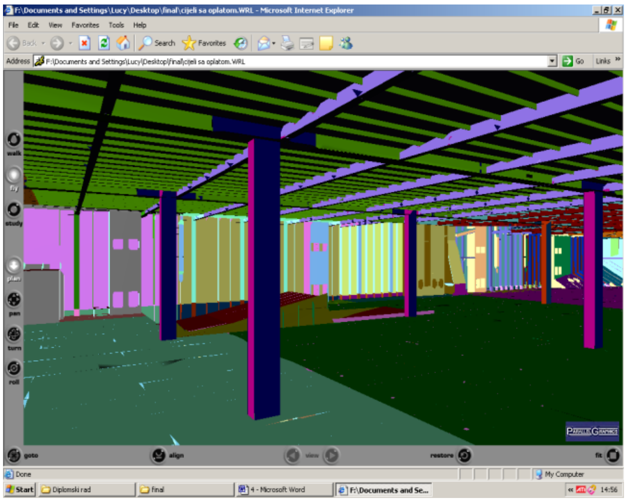

Fig. 11. Virtual model of car carrier ship construction

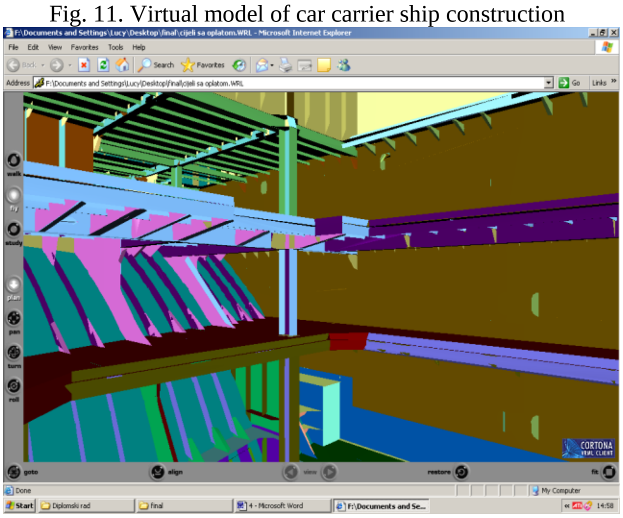

Fig. 12. Car carrier ship construction viewed in MS IE 6.0

The file is exported in VRLM format appropriate for network applications, having in mind its final view using for example the Microsoft Internet Explorer, Figs. 11, 12.

After the applied optimization procedure and data compression, the resulting file in VRLM format of reduced size is more appropriate for active virtual presentation in network environment. The two described approaches were applied to generate virtual model of a car-carrier built in shipyard Uljanik in Pula. The 3D solid element models for the purpose of this research were supplied by USCS from Pula for educational purposes on the Department of Naval Architecture and Ocean Engineering in Zagreb.

Examples of dynamic virtual modelling, Figs. 13. 14, or virtual modelling of dynamic behaviour of ships and marine objects in waves make use of the primary description of the hull shape [13]. The program for generation of VRLM files is produced in Fortran and the 3D environment presentation is prepared by using Visual Basic. The basic program in Fortran calculates hydrostatic properties or the hull, stability and ship responses to waves. Visualization is provided by Visual Basic/VRML module. The ship's hull is placed on the water line according to precalculated values of drafts, trim and heeling angles. During the calculation the values of amplitudes and periods of ship motions for rolling, peatching and heaving for selected heading to waves. Program have the modulus for geometric modelling of superstructures and loads on decks.

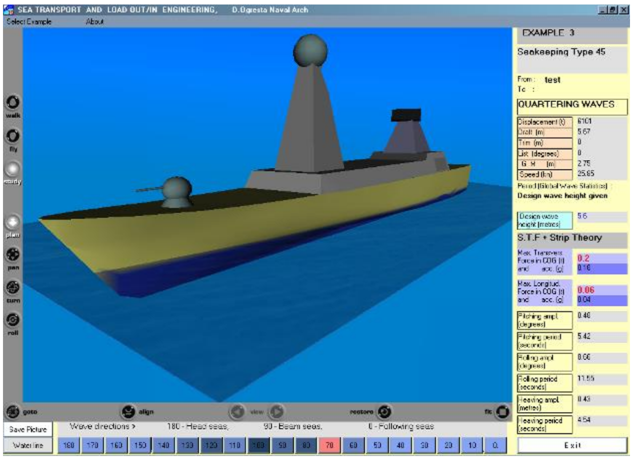

Fig. 13. 3D – Dynamical model – rolling / peaching / heaving of a warship

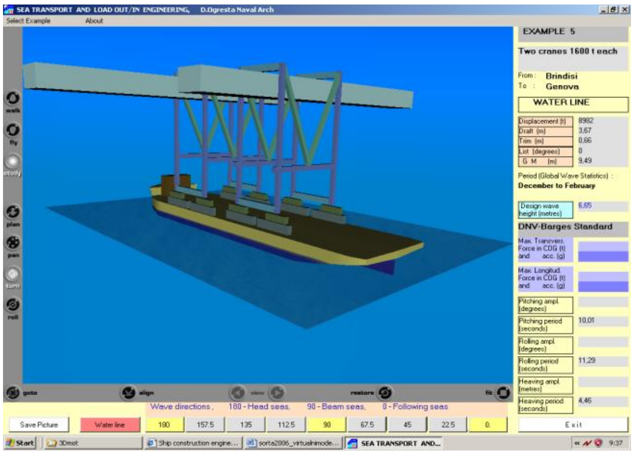

Fig. 14. 3D – Dynamical model – rolling / peaching / heaving of a heavy cargo lifter ship

The usage of precalulated data stored for dynamic behaviour is accomplished by interface written in Visual Basic, Figs. 13, 14.

V. GRID TECHNOLOGY

The GRID technology offers the missing opportunity for achieving the ultimate goal of photo elastic virtual presentations in shipbuilding in real time based on network environment. In addition, the navigation through complex models requires a number of guidelines and facilities for orientation in the space of the model that require a large amount of computational efforts. Therefore, by partitioning of large models in shipbuilding into number of submodels such as the hull, the bow, the stern, the engine room, superstructures, cargo holds and so on, the processing capacities can be distributed within the GID environment.

VI. CONCLUSION

This study investigated the possibilities for creation and generation of smaller and larger, static and dynamic 3D models in shipbuilding. The aim the research was to provide not only passive viewing of engineering objects but active, virtual investigation of the model space in real time in the network environment employing the nowadays advanced ICT technologies, CAD/CAM programming facilities for 3D and virtual modelling as well as the GRID techniques for acceleration of calculation procedures. Soon becomes obvious how the preparation of large scale photo-realistic virtual models is still a complex and time consuming effort in spite of the tremendous development in all fields of CAD and ICT. The efficient modelling still requires many simplifications and optimizations in applications of colours, textures, shadows, illuminations, textual descriptions in order to achieve the goal of interactive virtual photo-realistic presentation in real time and in network environment. Therefore the usage of GRID methodology can give additional impetus for virtual modelling of highly complex engineering objects in shipbuilding.

The experience in this study encourages that static and dynamic large scale virtual models with multimedial support and completed with appropriate technical descriptions offer challenging applications in shipbuilding in the ship's lifetime service, starting with the conceptual, preliminary and detailed design, production in shipyards, and later in training of the crew, inspection, repair and maintenance, Fig. 15.

Applications of virtual modelling in shipbuilding offer the opportunity for operationalization of virtual laboratories for future design and building procedures and particularly for research, development and education on all levels, Figs. 15 and 16. Virtual modelling and foundation of virtual laboratories is recommended by UNESCO as an opportunity for practicing of high technology achievements even in developing countries and communities [14]. Plans for implementation of virtual modelling and virtual laboratories are part of the developing strategies of many universities and institutes, such as CETENA from Genoa [15], Fig. 17. Virtual modelling is commonly considered as photo-realistic visualization and active walk through the model, functional generation of prototypes including motions, ergonomic, simulation of complex activities, scenarios of complex operations, different interactions among parts, compartmentation and virtual production based on robotics, manuals for inspection and maintenance, operation sequences and so on, Figs 15 and 16. However, according to UNESCO the virtual laboratory (or co-laboratory) is defined as digital working environment open for international cooperation and data, knowledge and experience interchange in research and development, creative activities and particularly in performing virtual experiments [14]. The aim of the virtual laboratories in their final application is not in replacing but in enriching of activities of real laboratories.

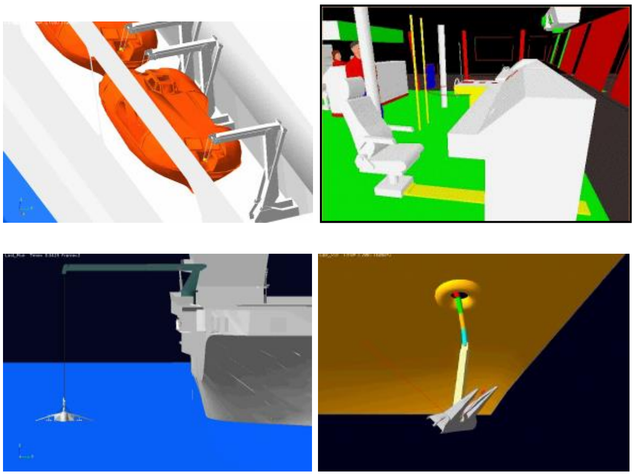

Fig. 15. Different applications of virtual modelling (CETENA)

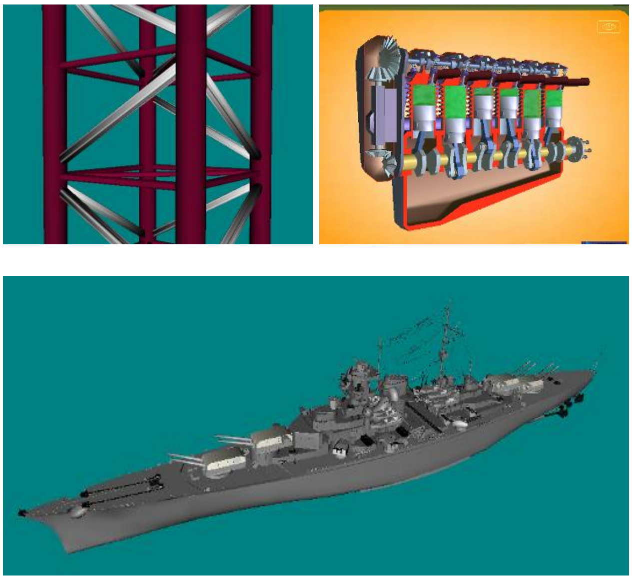

Fig. 16. Different applications of virtual modelling (Internet

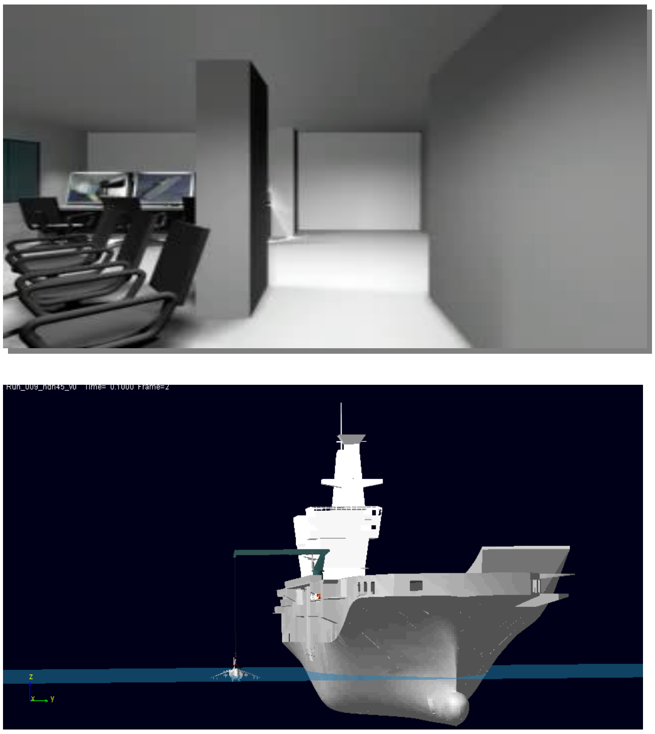

Fig. 17. Imagined virtual laboratory (CETENA)

The impression in this study is that in spite of numerous limitations the very detailed photo-realistic static and dynamic virtual models in shipbuilding equipped with necessary textures, colours, textual and voice multimedial descriptions, will enter different aspects of ship design, productions and service particularly if supported by GRID technology. Virtual laboratories will be inevitable applied in education on universities, research and development in institutes, in design approval, inspection and maintenance in classification societies with significant role in industry.

On 3D modelling in this study participated Božidar Medić, Tino Stanković, Petar Curać, Tomislav Tišljar and Bojan Marunica, former students on the Department of Naval Architecture and Ocean Engineering. The dynamic models are provided by Davor Ogresta now Independent Engineering Consultant with Noble Denton Consultants Ltd. The 3dD model of the car-carrier was given to the research group from USCS in Pula. Virtual models are available at www.fsb.hr/kziha/shipconstruction.

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